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Design and Analysis of Scissor Jack for Light Motor Vehicle

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Abstract - *Scissor jacks are simple mechanisms used to drive large loads over short distances in to translator motion. Most scissor jacks are similar in design. Consisting of four main memes driven by a power screw. The power screw of scissor jacks greatly reduces the amount of force required by the user to drive the mechanism. In this project work, a scissor jack was designed and analyzed which can be used for lifting the vehicle in vertical direction. A scissor jack is an example of a power screw in which a small force is applied in a horizontal plane for raising or lowering a large load. The purpose of this work is to design a scissor jack for safe, easy operation and which will able to lift the car without spending much effort, by studying the total deformation and von-mises stress values of the scissor jack which are useful for assessing the safety and life prediction of the scissor jack. A detailed structural analysis of scissor jack is performed using ANSYS and this analysis helps to predict which parts of the scissor jack fails when a certain external load acts on it. Automobile sectors are very keen at their productivity and customer satisfaction. We also keen at reducing the weight of scissor jack at the same time maintaining its strength and service life. We made certain change in manufacturing process thereby made a new versatile jack that can be used for varying models of L.M.V automobile sector. Also the new design that made by Pro-e software can be tested by ANSYS software.*

***Key Words*: Light motor vehicle, Scissor Jack, Power screw, Design, Ansys etc**

1. INTRODUCTION

A screw jack is a mechanical device used as a lifting device to lift heavy Loads or apply great forces jacks employs a screw or thread or hydraullic cylinder to appply linear forces. Car jacks use mechanical advantage to allow us to lift over greater distance. A scissor jack is a device constructed with a cross-hatch mechanism, much like a scissor. A commercially available scissor jack is shown in figure 1.

A scissor jack is operated by turning a lead screw. It is commonly used as car jacks. In the case of a scissor jack, a small force applied in the horizontle plane is used to raise or lower large load. A scissor jack's compressive force is obtained through the tension force applied by its lead screw. An acme thread is most often used as this thread is very strong and can resist the large laods imposed on most jacks while not being dramatically weakened by wear over many rotations. An inherent advantage is that, if the tapered sides of the screw wear, the mating nut automatically comes into closer ebgagement, instead of allowing backlash to develop. These types are self-locking, which makes them instrinsically safer other than jack technologies like hydraulic actuators which require continual pressure to remain in a locked position. The completed cad design of the scissor jack is shown in the figure1

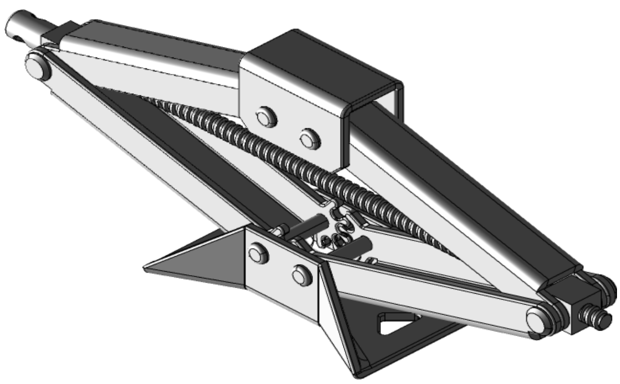

Fig -1: Scissor Jack

2. TYPES OF JACK

2.1 Mechanical Jack

A jack is mechanical lifting device used to apply great forces or lift heavy laods.a mechanical jack employs a screw thread for lifting heavy equipment. Jacks employ a screw thread or hydraulic cylinder to apply very high linear forces. The most common form is a car jack, floor jack or garage jack which lifts vehicles so that maintenance can be performed. Car jacks usually use mechanical advantage to allow a human to lift a vehicle by manual force alone. More powerful jacks use hydraulic power to provide more lift over greater distances. Mechanical jacks are usually rated for a maximum lifting capacity.

2.2 Scissor Jack

A Scissor jacks is a device constructed with a cross- hatch mechanicsm, much like a scissor, to lift up a vehicle for repair or storage. The jack opens and folds closed, applying pressure to the bottom supports along the crossed pattern to move the lift. When closed they, have a diamond shape. Scissor jacks are simple mechanism used to drive large laods

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short distances. Most scissor jack is oprated simply by turning a small crank that is inserted into one end of the scissor jack. This crank is usually "Z" shaped. The end fits into a ring hole mounted on the end of the screw, which is the object of force on the scissor jack. When this crank is turned, the screw turns, and this raises the jack. The screw acts like a gear mechanism. It has teeth (the screw thread), which turns and move the two arms, producing work, just by turning this screw thread, the scissor jack can lift a vehicle that is several thousand pounds.

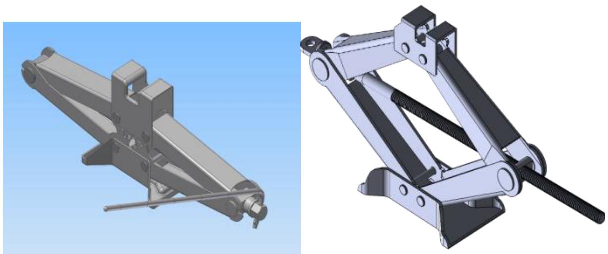
2.3 Different Types of Jack

Jacks are used for lifting heavy weights by applying a force on it. The different names for the jacks are given depending upon the design, utility, technology used and customization etc. Some of the important jacks used for lifting are given below:

1. Scissor jack.
2. Hydraulic jack.
3. House jack/Screw jack.
4. Pallet jack.
5. Floor jack.
6. Pneumatic jack.
7. Bottle jack.
8. Farm jack.

2.4 Construction of a Scissor Jack

All the different scissor jacks are similar in design which consists of a base plate, four lifting arms, a carrier plate, eight connection pins, two connection members, a crank and a power screw. The four metal pieces are connected to each other at the corners with a bolt. A scissor jack is having a diamond shape frame with a nut at one side and a sleeve on the other side. The nut and sleeve is supported by a screw. When the screw is rotated, the nut moves away or towards from the sleeve depending on the direction of the rotation. The rotation will either lift-up or lower down the vehicle which is supported on the scissor jack. All the different positons of the scissor jack are shown in Fig 2.



(a) (b)

Fig- 2: (a) scissor jack at lowest position (b) scissor jack at Maximum position

Problem Statement

Nowadays in our country, most of the cars were equipped with the scissor car jack. We found that the car jack were very difficult to be used especially by women, we want to develop a product based from the problem faced by the users who drive a car regarding to this issue.to overcome this problem, a research has been conducted to find the solution on how to design a jack for the light motor vechicle using the simplest and cheapest way it is energy saving. Although there were many ways to solve this problem, we recommend that the design this car jack system is the practical way when we considered all the factors and consequences especially about the analysis to develop this product. During the research, we have found that most of the car user has difficulties in maintaining their vehicles breakdown especially light motor vehicles in the scope changing tires. The normal car jack we have in the market is opertaed using bare hands and it is time consuming. It also requires much energy from the person to rotate the jack. Hence this report had been prepared to recommend the design of the car jack that is user friendly and easier to operate as do not required too much money to develop this product. With reference to real life experiences and research papers following problems were identified in the existing model.

- Car Jack is heavy operational equipment and it requires rigorous human efforts to lift the load of vehicle.
- Existing scissor jacks are based on power screw principle, hence required to apply large number of efforts in rotational direction.
- As the Nut dimensions are small, extra connecting features need to add to lift the load. Hence connecting bended rod is provided and as the surface is smooth, it will cause loss of efforts due slippage and sliding of connecting rod.
- As Jacks, width is comparatively small than length & height, there may be chance of sliding, bending and major accident when jack is loaded by car weight.

Limitations

1. Elements of this system have to manufacture separately to a high degree of precision which increases the overall manufacturing cost of the system.
2. Higher degree of maintenance is required and hence maintenance cost is increased.
3. The entire system is subjected to mechanical friction, hence regular lubrication must be provided.
4. Additional protection against rust and corrosion is required.

3. DESIGN & METHODOLOGY

The design starts with the set of all possible equations bounded by the external constrains and by a process of

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progr essive evaluation and selection narrows down the range of candidates to find the 'best' design for the purpose. There are so many steps are there in the design process. Specifically we design the single mechanical scissor jack components such as it's:

- upper link
- lower link
- base plate
- power screw
- fixed nut (screw housing)
- main nut(protective)
- driving handle

Chart -1: Flow Chart

3.2 Selection of Material

Scissor jacks are usually made of materials that are very strong and are suitable for withstanding heavier loads on it. Steel is selected as material for scissor jack because of its durability.

Table -1: Material Properties of Steel

Sr No.	Properties	Values
1	Density (Kg/m3)	7800
2	Young's Modulus (Mpa)	210000
3	Yield Strength (Mpa)	360
4	Tensile Strength (Mpa)	610
5	Poisson's Ratio	0.3

3.3 Components of Screw Jack

1. Power screw
2. Rivets
3. Coupling nut
4. Crank (Handle)

3.4 Design Calculations

A. Design of Power Screw

1) Direst Tesnile Stress (σt)

σ_t= axial load / AC

Design stress (σ_d) = yield stress / F.S = σy / F.S

Where (F.S=2.5)

σ_d = σ_{all} = 280Mpa / 2.5 all

σ_{all} = 112Mpa

Now σ_d σ_t = |F_t | / AC = 4F_E / πdc^2

dc √{(4*27574.6)/ (π*112*106)}

dc 0.0177m =17.7 mm

dc 17.7 mm ≈18 mm

Take pitch (p) = 4 mm

Major diameter (do) = dc + p = 18+ 4 =22 mm

Mean diameter (dm) = dc p/2 = 18 4/2 = 16 mm

AC = πdc / 4 =254.469 or 2.54 * 10 2 mm2 -4m2

Tensile stress (σt) = |FE| / AC

= 27,574.6 / 2.54 * 10-4m2

= 108.56 Mpa

So,

Which implies σ_{all} $\sigma_{t;}$ which means design is safe for the power screw.

Shear Stress Due to Axial Loading

= |FE| / πnd$_c$t

But,

t = pitch / 2 = 4 / 2 = 2

Where,

Assume the length of nut = 20 mm

n = length of nut / pitch = 20 / 4 = 5

= (27,574.6) / (π* 5*18*2)

= 48.743 Mpa

Assume the load is uniformly distributed over threaded contact.

2) Design of Nut (Power Screw):

Material selection:-

- Cast iron
- Safe bearing pressure 12.6 – 17.6Mpa
- σy =276Mpa and σnt = 414Mpa

Pb = |FE| / (π/4)(do^2 – dc^2)n

Pb = |FE t_n) | / (πd_p

Where;

Width of thread t = p/2 =4/2 = 2

P_b =15 Mpa

n = F.s

n = |FE| / d_p * t *p_b

n = (27,574.6) / (π * 16 *10-3 * 2 * 15*106)

= 18.27; take F.s ≈ 18

Shear Stress onthe Nut Threads

τ_{max} = |FE| / (π* do *t *n)

= 27,574.6 N / (π * 36 * 2*18) outer diameter D=36mm

= 6.7698 Mpa

σ_{sy} = 0.577 σ y

= 0.577 * 276 Mpa

= 159.252 Mpa

τ_{max} = σsy /F.S ;

F.s = 159.252 / 6.7698 = 23.52 ≈ 24 it is satisfactory

Shear stress on the part of supporting arms

τ = |FE| / A = |FE| / (πd2/4)

But σ = σ all y / F.S =276 / 2.5 = 110.4Mpa

σ_{sy} =0.577 * σy = 0.577 * 276 = 159.252Mpa

τ_{max} = σ_{sy} /F.s=159.252 / 2.5 = 63.7Mpa

d = ((4*27,574.6N) / π (63.7*106)) < τ_{max} = 63.7Mpa

Then d > √ ((4 * 27,574.6N) / π (63.7*106)) > 23.4mm

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3) Design of Base Plate:

Here the base plate should with stand the applied load plus the whole component or linkage load by itself, the force, we have to select the material during the design process in order to resist the above all loads. And the base must be grooved to protect sliding of the jack during application.

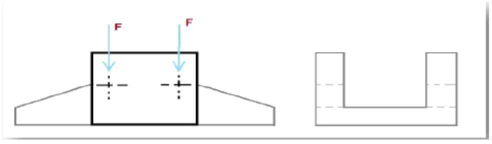

Fig -3: Base Plate

Material Selection

- steel alloy AISI-1030
- normalized(8400)
- σ_y = 645 Mpa, σ = 1015Mpa and F.s= 2.5 nt

Now, $\sigma_{all} = \sigma_y$ /F.s= 645 / 2.5 =258 Mpa

Bearing Stress

σ_b = (F) /td = F / td;

Where; d = diameter of the rivet through the fastener hole

t = thickness of the fastener hole

$\sigma_b = F / td < \sigma_{all}$

$t > F / d\, \sigma_{all}$

t > 27,574.6 / 16 * 262

t > 6.578 mm

Then, take any value above 6.578 mm, let t = 7mm it will be safe.

4) Design of Upper Arm:

Upper arm is used to transfer the load applied to the screw driver housing (connected mechanism).The links (arms) are subjected to bending stress due to the applied load on the counter of gravity of those links at a point. And we should assume that the load is distributed over the surface of the links.

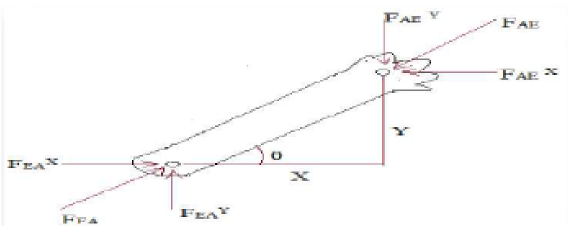

Fig -4: Upper arm strength analysis

Bending Stress

When θ = 800 and L = 111.697 mm at maximum height

X = L Cos θ = 111.697 * Cos 800 = 19.396 mm

Y = L Sin θ = 111.697 * Sin 800 = 110 .000071mm 110 mm

$+ɔME = M - F_{AE}{}^{Y}X + F_{AE}{}^{X}Y = 0$

M = 13,787.3 cos 10*19.396 – 13,787.3 cos 80⁰*110

= 263,355.78 – 263,355.347

= 0.4363 N-mm

5) Design of Lower Arm:

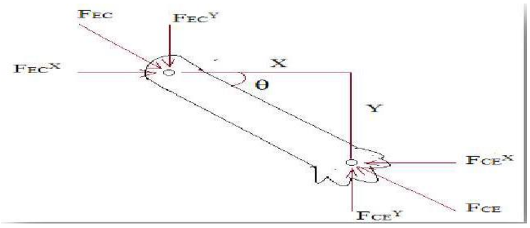

Fig -5: Lower arm strength analysis

Bending Stress

When

θ = 800 and L = 111.697 mm at maximum height

X = L Cos θ = 111.697 * Cos 800 = 19.396 mm

Y = L Sin θ = 111.697 * Sin 800 = 110.0000716 mm 110mm

$+ɔME = M + F_{EC}{}^{X}Y - F_{EC}{}^{Y}X = 0$

M = 13,787.3sin80 13,787.3cos80 0(19.396) – 0(110)

= - 0.4363 N-mm; change assumption +ɔM = 0

Then, M = 0.4363N-mm

4. MODELING OF SCISSOR JACK

All the different parts of the scissor jack are modelled in Ansys software by using different commands and all the individual parts of the scissor jack are assembled in the ansys software.

1) Supporting Frame

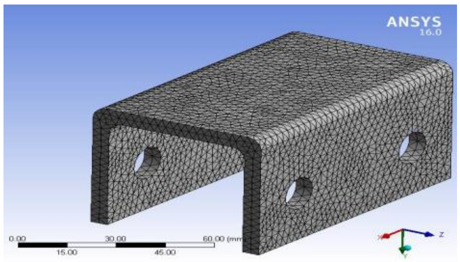

Fig -6: Supporting Frame

2) Base:

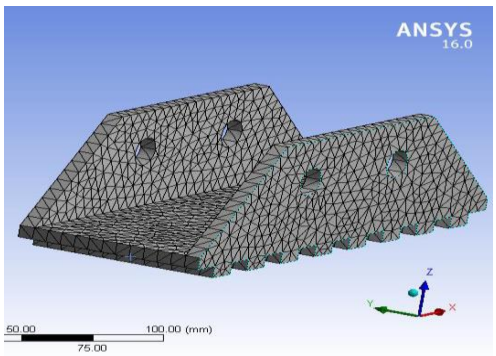

Fig -7: Supporting Frame

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3) Link:

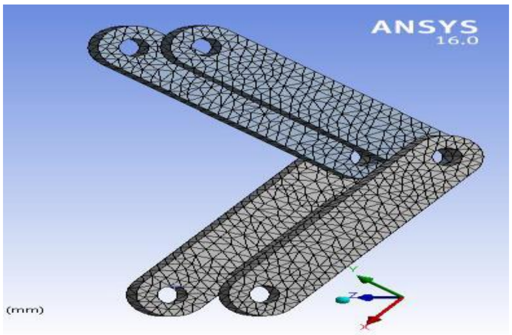

Fig -8: Link

4) Scissor Jack with Mesh:

After assigning element type to the scissor jack, the created Catia model is converted into IGES format and imported into ANSYS Workbench. Meshing is an important process of an analysis and it should be performed on the scissor jack model. Meshing is the process of dividing the created model in number of divisions or elements which consists of nodes. By meshing process, we can determine the efficiency and effectiveness of any analysis. An automated mesh generation is as shown in Fig. 9

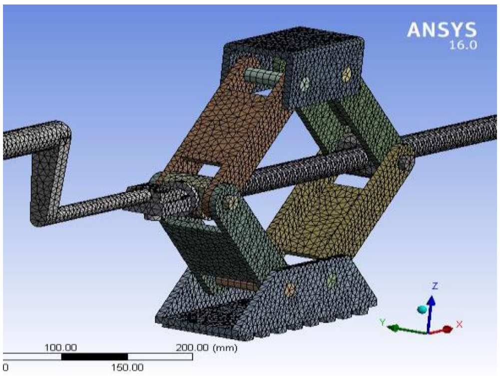

Fig -9: Meshing of Scissor Jack

4) **Total Deformation:**

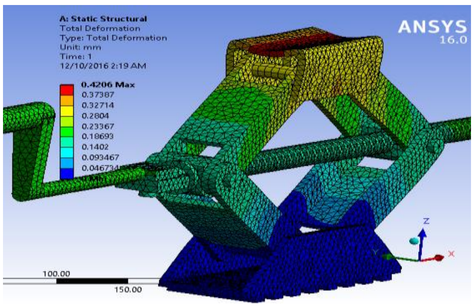

Fig -10: Total Deforamtion

5. RESULT AND DISCUSSION

	Therotical Result		Ansys Result	
Element	**σt_{max} Mpa**	**σ_b (MPa)**	**σt_{max} MPa**	**σ_b MPa**
Supporting Frame	197.334	342	212.22	352
Base	148.866	258	156.22	268.3
link	373.896	246.2	391.5	258.9
Assembly	392.22	368.5	409.3	374.5

Where, σ_{tmax} - Max.principal tensile stress
σ_b - bearing stress

By observing the result steel is also falls under the safe limit so it can also be consider for manufacturing purpose of scissors jack.

The calculation is made manually and comparing it with ANSYS software to get better and reliable result.

6. CONCLUSION

The project work will include a design and analysis of scissor jack for light motor vehicle and other same type of variants. By analyzing above results of scissor jack we have concludes that: Improvement in structural capacity of scissor jack and % reduction in material and also this is a common jack for the variant. The designed jack has the reduced weight (by changing the manufacturability). Designing this new jack reduces the number of parts for simplifying the assembly process. Only rivet joints are induced (Removal of welding to avoid distortion).

A scissor jack is modelled in catia V5 and a structural analysis of scissor jack with a force of 5000 N is performed in ANSYS software. The total deformation and von-mises stress of the scissor jack is analysed. From the results, it is observed that the maximum deformation and the von-mises stress of the scissor jack are within the limits. Therefore, modelled scissor jack is safe to use and has long life.

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